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Analysis of the Thermal Shielding Properties of Camouflage Materials

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ABSTRACT

In a previous paper, we discussed our techniques for measuring the thermal shielding of materials. Two heated panels served as surrogates for heated vehicle components, such as armor heated by the engine. The outer surface of each panel was thermostatically controlled to the same temperature. The camouflage material covered one of the panels, while the other, uncovered, panel acted as the baseline. Periodically, we collected calibrated infrared images of the two panels at 3 to 5 and 8 to 12 microns. In this paper, we present techniques to analyze further data from these measurements. The goal of the analysis is to quantify the relative capability of materials to shield from view warm vehicle components. We also present results of a simple experiment to measure the effect of air movement on the shielding properties of the materials.

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Introduction

The function of an infrared camouflage material is to blend the signature of ground vehicle with the signature of the surrounding area. For unheated areas of the vehicle, the material should track the signature of the background area as conditions change with weather and solar load. For heated area, however, the material must shield from view hot areas on the vehicle.

Consider, for example, the M113 armored personnel carrier in Figure 1. The engine heats the area at the front of the right side of the vehicle. To be effective, a camouflage material should shield this hot signature from the view of enemy

Measurement Techniques

To evaluate how well camouflage materials perform this shielding function, we designed the indoor test set up in Figure 2. Infrared cameras record images in the 3 to 5 (medium wave) and 8 to 12 (long wave) micron bands.

Figure 3 illustrates the construction of these heated panels. The outer surface is 0.25 in. aluminum painted with green CARC paint. Behind the aluminum, a 500 watt element supplies heat to raise the temperature of the outer surface. A thermocouple on the outer surface and a control system maintains the temperature at the desired level, Figures 7 and 8. The system controls the spatial variation of the temperature to about + or – 3 deg C and the temporal variation to about + or – 0.25 deg C. Figures 4, 5 and 6 show how the test materials are arranged to cover heated and unheated panels. We leave portions of the heated and unheated panels uncovered for comparison.

Using this measurement set up, we begin by allowing the panels to stabilize to 46 deg C with the fan off. We then hang the test materials on the fixture, and take thermal images each minute for 20 minutes. Finally, we repeat the procedure with the fan on for convection cooling.infrared viewers.

Analysis Techniques

Figure 7 illustrates typical results from these measurements. To analyze this data, we estimate parameters to characterize the experimental curves. Using Solver in Microsoft Excel, we perform a least squares to

$$T(t) = T_{final} - (T_{final} - T_{initial})e^{-\frac{t}{\tau}}$$

where $T_{initial}$ is the beginning temperature, T_{final} is the ultimate temperature and τ is the time constant.

As a measure of the effectiveness of thermal shielding, we plot

$$\Delta T = T_{final} - T_{unheated\ panel}$$

where $T_{unheated\ panel}$ is the apparent temperature of the corresponding unheated panel.

Results and Discussion

The results of fitting this curve for the apparent temperature for long wave (LW) infrared is plotted in Figure 8. Note that all of the materials shielded the hot panel to some extent. The best materials are an artificial grass and the two TBE materials. Figure 9 adds the medium wave (MW) apparent temperature results to this plot. The materials all behave similarly for LW and MW.

The addition of forced convection from a fan does change the apparent temperatures, as would be expected, Figure 10. The bare panel is somewhat cooler, but almost all the materials are more effective at thermal shielding.

Conclusions

The techniques shown are suitable for evaluating the thermal shielding performance of camouflage materials. Because air flow has a strong influence on thermal shielding performance of camouflage materials, future measurements should include precise control of air flow.

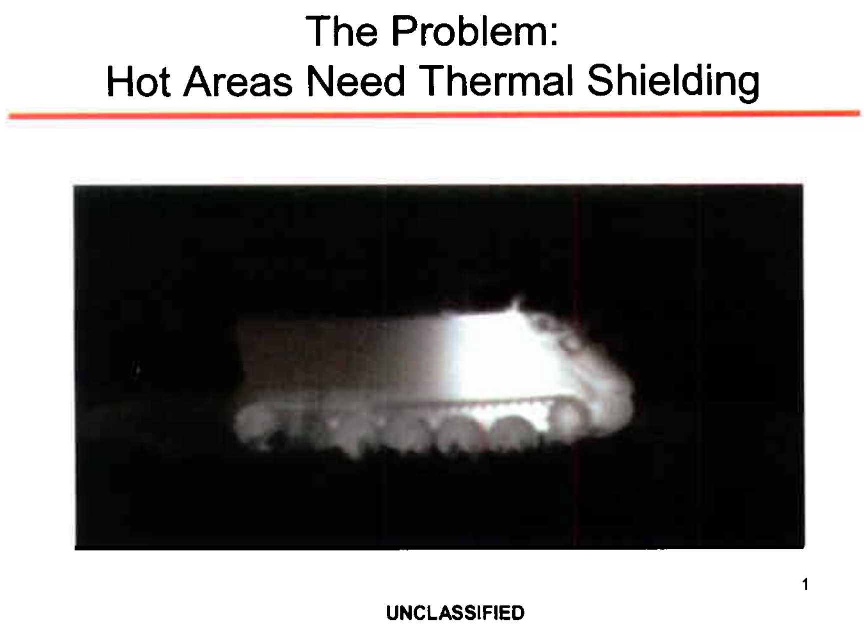

Figure 1. The problem requiring thermal shielding.

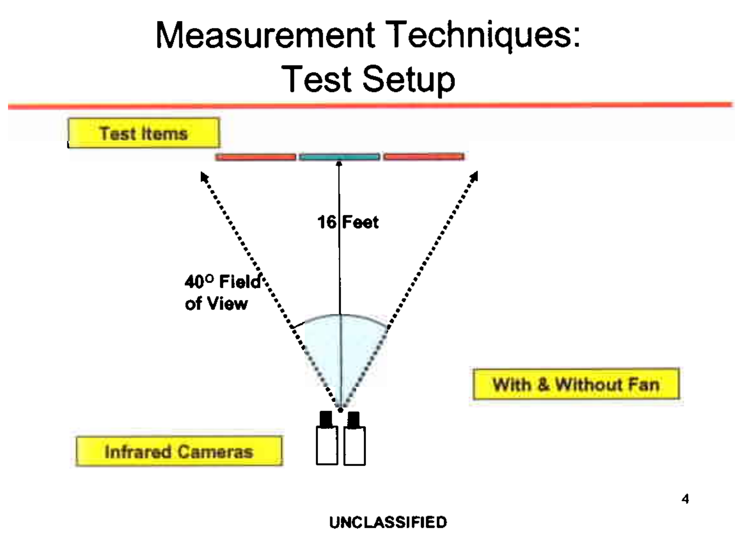

Figure 2. The measurement setup.

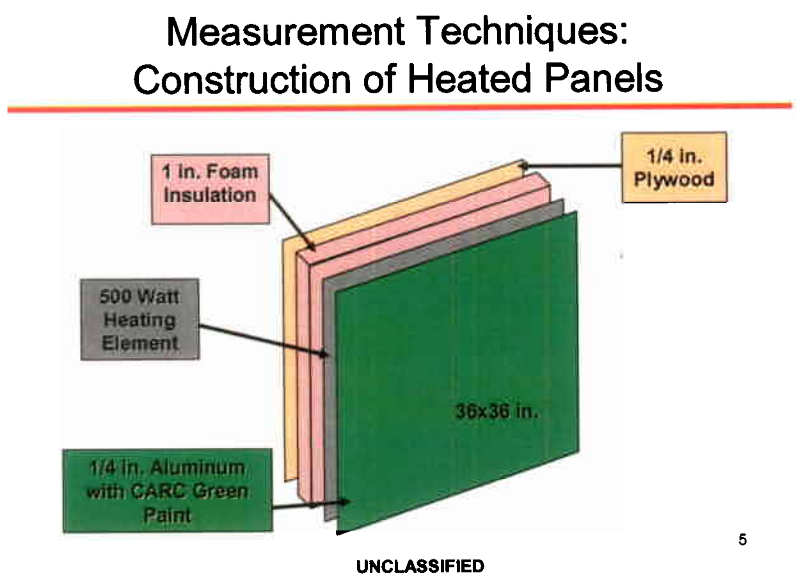

Figure 3. Construction of heated panels.

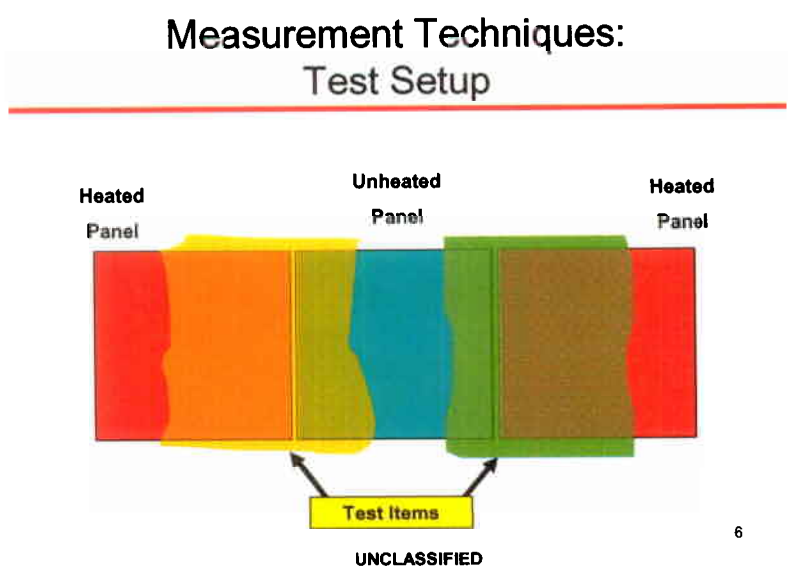

Figure 4. Position of test items.

Measurement Techniques: Arrangement of Test Items

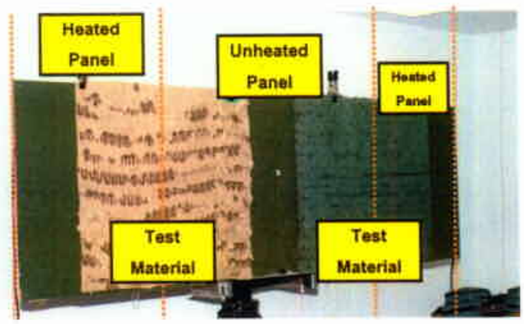

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Figure 5. Position of test items.

Measurement Techniques: Arrangement of Test Items

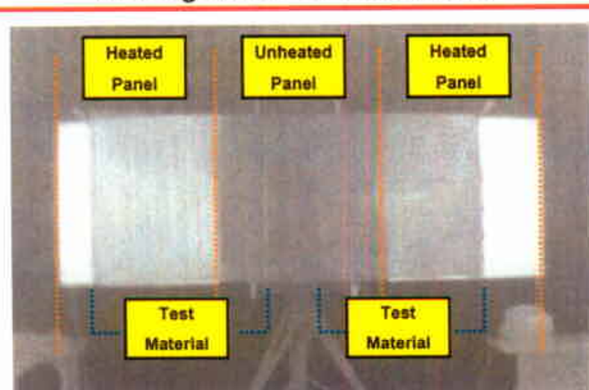

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Figure 6. Position of test items.

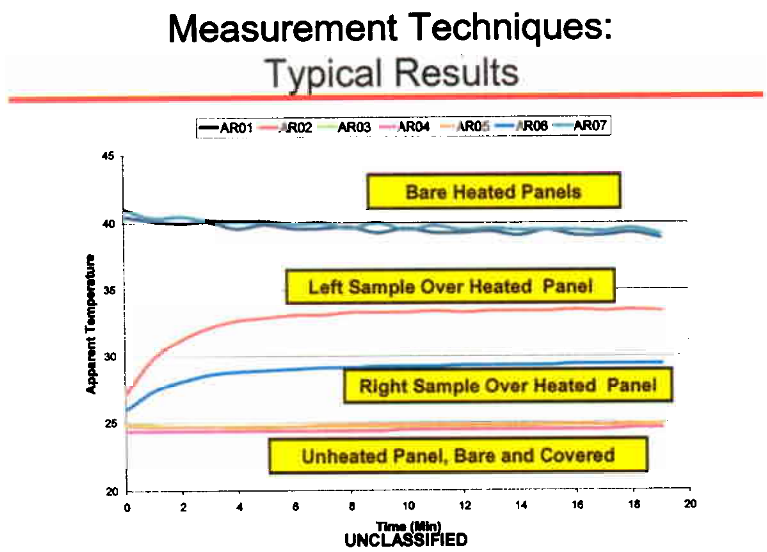

Figure 7. Typical results.

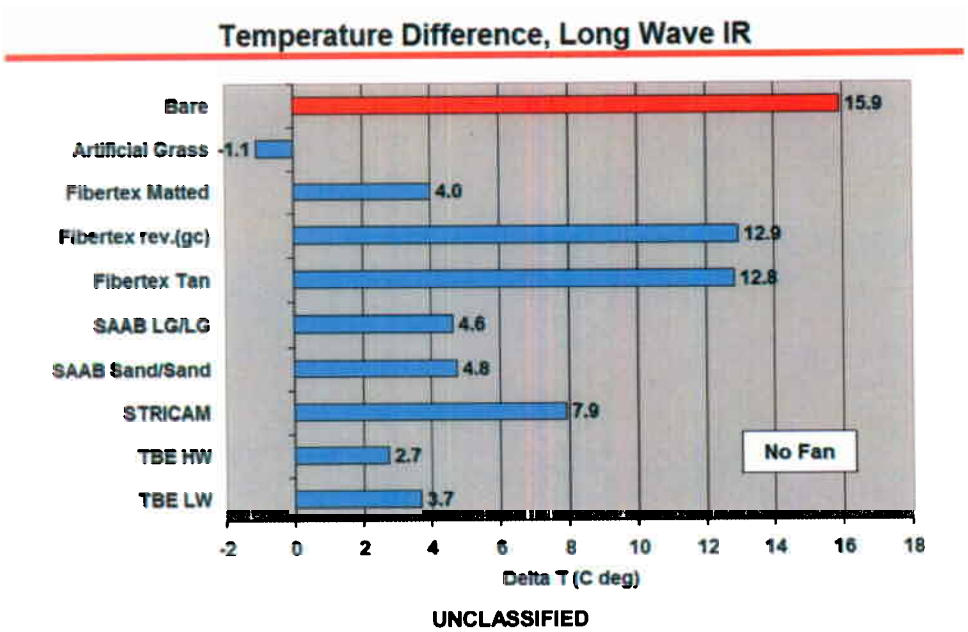

Figure 8. Long wave performance with no fan.

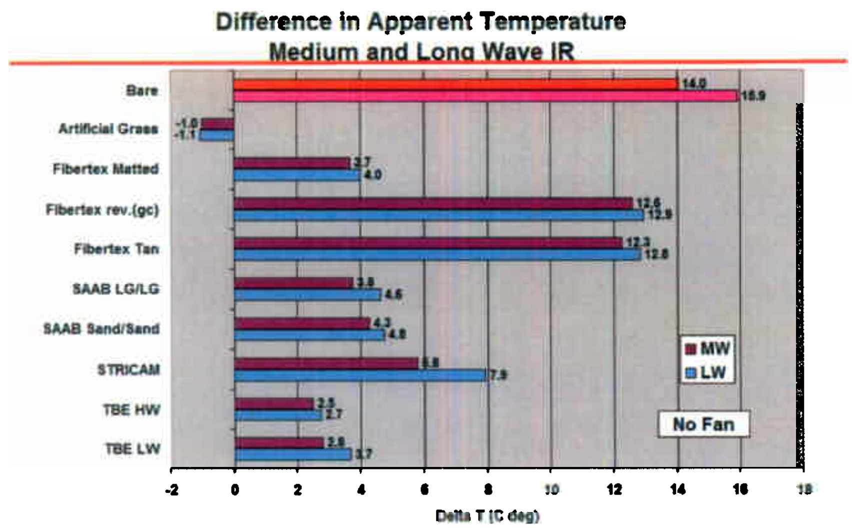

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Figure 9. Long and medium wave performance with no fan.

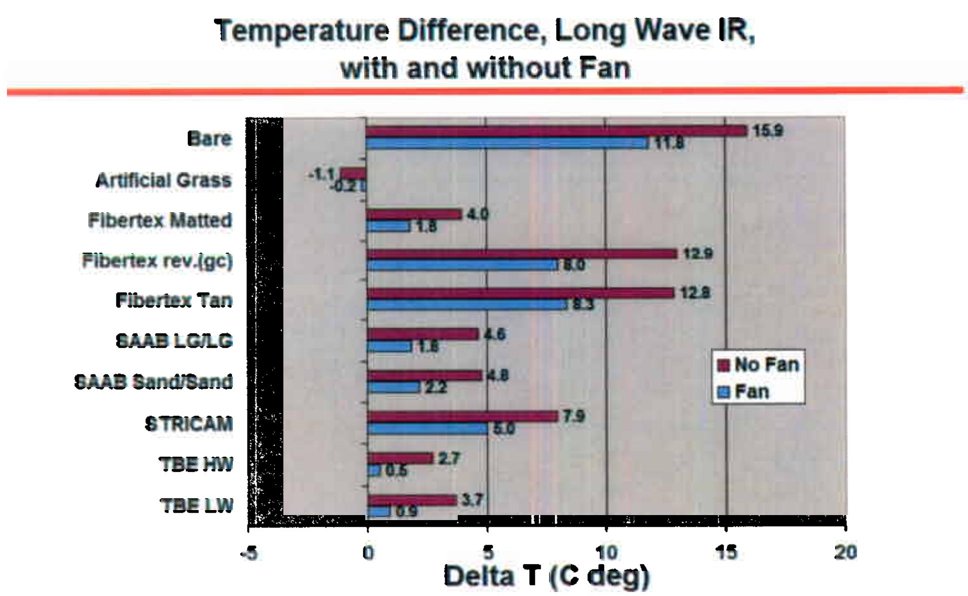

Figure 10. Long wave performance with and without a fan.